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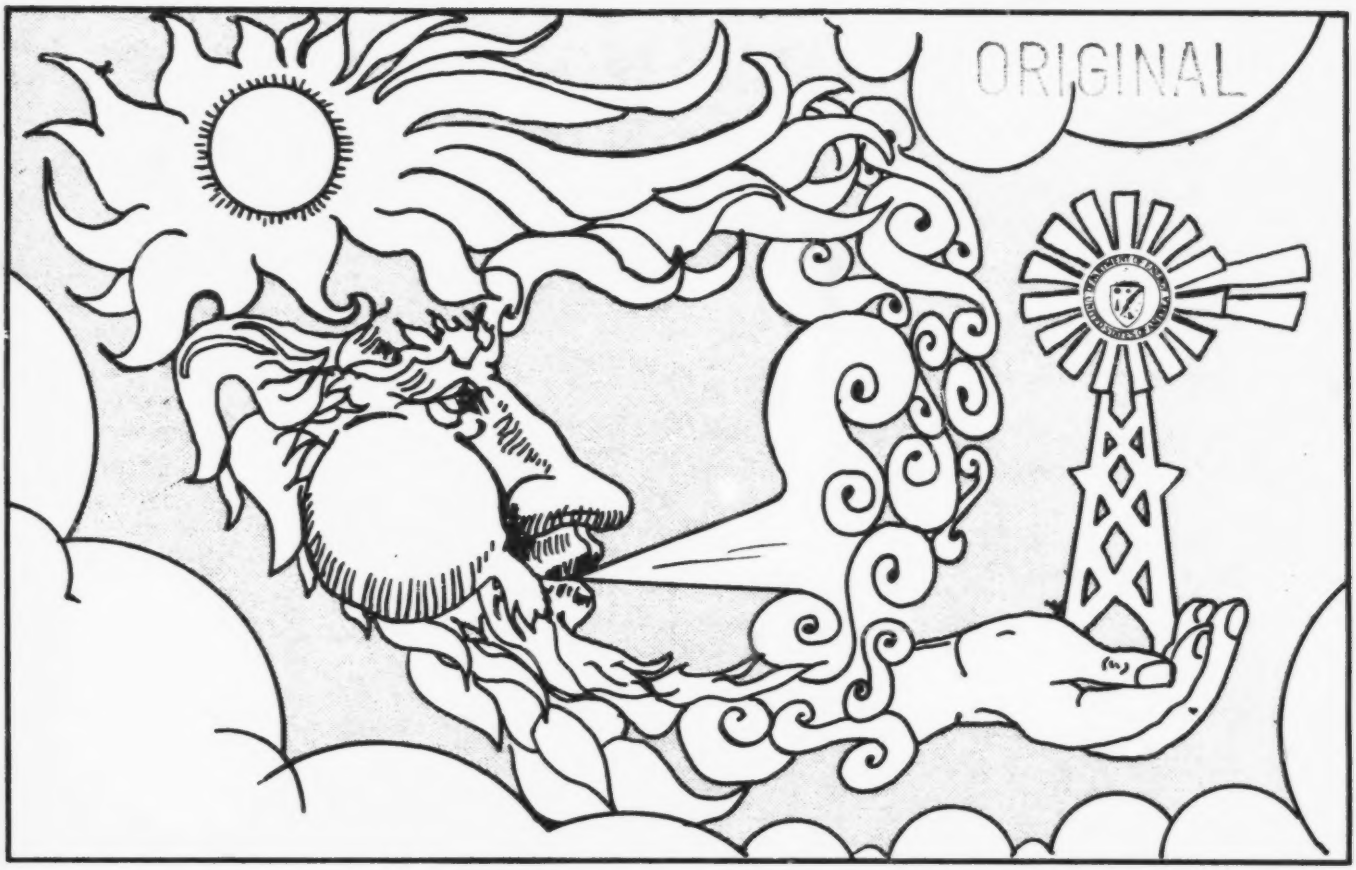
Small-Scale Appropriate Energy Technology Grants Program



PACIFIC SOUTHWEST REGION
UNITED STATES DEPARTMENT of ENERGY

Solar Energy For Composting Toilets

FINAL REPORT

SOLAR ENERGY UTILIZATION IN COMPOSTING TOILETS

GRANT NO. EM-78-03-1978

Prepared For: Small-Scale Appropriate
Energy Technology Grants Program
Region IX
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San Francisco, CA 94105

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U.S. DEPARTMENT OF ENERGY

SMALL SCALE
APPROPRIATE ENERGY TECHNOLOGY GRANTS PROGRAM

REGION IX

BACKGROUND

In his energy message of 1977, President Carter stated that a balanced energy program should seek out the talents of individual inventors and small businesses and groups. Congress subsequently authorized the Energy Research and Development Administration (now the Department of Energy, DOE) to undertake a grants program in small-scale, energy-related technologies referred to as appropriate technologies because they are "Appropriate" to local needs and skills. This small grants program has come to be known as the Appropriate Energy Technology (AET) Program.

WHAT

A regional pilot program in appropriate energy technology was implemented to provide monetary grants for small-scale, energy related projects for;

- o Idea development, for concepts demonstrating potential;
- o Concepts testing, for projects that have gone beyond the idea-development phase and are ready for testing;
- o Demonstration, to develop projects which, having been tested, now must be proven through actual use.

In terms of resources, Appropriate Energy Technology ...

- o makes the best use of available renewable energy sources
- o conserves nonrenewable resources
- o depends largely on human labor
- o emphasizes use of local materials and labor skills

In scale and efficiency, Appropriate Energy Technology ...

- o is efficient in its use of energy and other resources
- o is simple to install, operate and maintain
- o is compatible with community regulations
- o may employ scaled-down industrial technology
- o employs novel application of existing technologies
- o emphasizes decentralized technologies

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In relation to the end-user, Appropriate Energy Technology ...

- o satisfies local needs
- o increases community energy understanding and self-reliance
- o is environmentally sound
- o results in durable recyclable systems and/or products

WHERE — The Region IX program covers the states of Arizona, California, Hawaii, and Nevada, as well as American Samoa, Guam, and the Pacific Trust Territories. This program is managed by the Office of the Regional Representative, Region IX, of the U.S. Development of Energy. Similar programs are being managed through the other nine regional offices around the country.

WHO — Eligible projects can come from

- o individual
- o local nonprofit organizations and institutions
- o state and local agencies
- o American Indian tribes
- o Small businesses

WHEN — Contact the regional DOE offices for the annual awards cycle

RESULTS — Over one hundred and eight applicants in Region IX have been granted funds with which to start or continue their projects during the first three years of the Appropriate Energy Technology Program.

For additional information on this program, please contact:

Small Scale Appropriate Energy Technology
U.S. Department of Energy
333 Market Street, 7th Floor
San Francisco, California 94105

Nationally, the Small-Scale Appropriate Energy Technology Grants Program is directed by the Office of Small-Scale Technology, U.S. Department of Energy, Washington, D.C.

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PROJECT SUMMARY

Solar Energy Utilization with Compost Toilets

A compost toilet is a waterless individual on-site human waste management device which uses biological processes to decompose wastes into a reusable humus-like end product. General problems with compost toilet operation have been: 1) Vectors gaining access to the wastes. 2) liquid buildup (faster than evaporation). 3) Odor problems from the toilet. 4) Health issues relating to the pathogenic nature of the humus end product (incomplete treatment). Manufacturers of commercial compost toilets have added electrical heat tapes, fans, and pumps to different models in an effort to alleviate some of these problems. Thus the compost toilet evolved from an energy saving device to an energy consumer in an effort to make it more trouble free and automatic so that it would be more generally acceptable to the public at large and health officials in particular.

The goal of the DOE study was to utilize solar energy in lieu of electricity to help alleviate the basic problems with compost toilets. Solar devices were first used to improve the performance of existing facilities and additional systems were designed from inception with solar heating and venting systems. Four independent studies were initiated and executed over the two years of the grant period.

1) The design and construction of a solar pasteurization unit for treatment of 55-gal drum waste collecton units.

2) Retrofit of an existing Clivus Multrum toilet for direct passive solar heat gain.

3) Design and construction of an owner-built flow-through compost toilet with a solar hot air heating system for hill side installation.

4) Design and construction of an integrated bathroom facility that included a solar heated flow-through compost toilet with a solar chimney venting system.

The solar pasteurizer (a large solar oven) was able to heat a 55-gal. drum 3/4 full of privy wastes above 55 degrees C in one week of labor intensive operation (opening and closing an insulated lid at 10 am and 2 pm solar time). However, the management requirement seemed excessive and the investigations were discontinued.

A Clivus Multrum was installed in a greenhouse and painted black for direct solar heat gain. The vent stack was insulated and a wind turbin vent cap added to aid exhaust. Four thermo couple probes measured inlet air, compost, inside air, and exhaust temperatures. Compost temperatures were not significantly higher than non-solar controls. The Clivus began ponding

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after one year of light use. Several recommendations are made in the body of the report.

An owner built flow-through toilet was built using a ferrocement stucco over insulated wood framed construction. A hillside installation allowed placement of the solar collector below the compost chamber inducing thermo convection of heated air up through the compost and out the vent stack. Constant overloading of the facility prevented a conclusive study of the unit's performance. Thermophilic temperature ranges were not attained by the compost. Further study under more controlled cirucumstances would produce more conclusive results.

The integral solar bathroom demonstrates water and energy conservation and alternative energy utilization specific to the bathroom. The toilet venting system did not perform satisfactorily as designed and odors were increased rather than alleviated. Thermophilic temperatures were not reached in the compost. Further study is recommended under controlled use rate after several design modfications have been made.

In general, the use of high temperature solar devices to enhance the biological process of composting within a privy vault was not successful. The compost toilets in the study demonstrated their vulnerability to shock over loading characteristic of public facilities and therefore demonstrated their unsuitability for such applications. However, their performance under more controlled use rates (at or below design maximum) merits further study.

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COMPOST TOILETS: BACKGROUND INFORMATION

Definition

A compost toilet is a waterless on-site human waste management device which decomposes wastes into usable humus. Its components include a toilet or privy stool which corresponds to the porcelain bowl in a standard flush toilet. A composting chamber directly below the toilet structure receives the wastes and is where the decomposition process takes place through the action of bacteria, fungi, yeasts, other microbes, and eventually some form of macrophyte (worms, insects, arachnids, etc.). The end product of this decomposition is the organic constituent of soil - humus.

This manipulated process of decomposition is called composting and refers to a technique for producing a soil amendment for fertility enhancement of agricultural or horticultural soils. There are two basic classes of microbial decomposition: Aerobic decomposition, or that which takes place within the presence of air or free oxygen; and anaerobic, that which takes place without air or free oxygen. Of the two, aerobic is generally faster and more active because it involves greater variety of organisms. The aerobic process generates heat (exothermic or auto heating) under proper conditions due to the high metabolic activity and this heat affects the chemical structure of the wastes and facilitates decomposition. Anaerobic decomposition, on the other hand, takes place at ambient temperature and at a rate proportional to that temperature. Fewer species and varieties of organism are involved and the process is characterized by the release of malodorous gases.

Aerobic Decomposition

In compost toilets, aerobic decomposition is more desirable than anerobic for the following reasons:

- Decomposition occurs at a faster rate.
- Fewer strong odors are generated or released.
- The heat generated from aerobic decomposition can potentially kill off any existing pathogens or parasitic organisms and their eggs or larvae thus producing a safer end product.

Conditions for Decomposition

In order to function properly and autoheat in the thermophilic range certain conditions must be present: There must be adequate moisture,

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with the decomposing mass damp but not soggy (this will exclude air and cause the pile to go anaerobic); there must be enough aeration to provide sufficient oxygen for microbial metabolism; there must be adequate ventilation to allow the gases which are a by product of decomposition to escape; finally there must be a proper balance of carbon to nitrogen atoms (20:1 to 40:1 C/N).

Human waste consists of liquid urine (1 qt/person/day) and semi-liquid feces (½ lb.person/day at 85% mositure). The carbon/nitrogen ratio of human wastes is very low (12).[1] For proper composting in a toilet, therefore, a certain amount of dry, carbonaceous material must be added and mixed in with the wastes in order to absorb the excess moisture and balance the C/N ratio. Grassclippings, wood ashes, dry soil, corncobs, weeds and garden wastes have all been used, in varying proportions, as admixtures.

In addition to meeting the biological requirements for decomposition, a compost toilet must also meet certain public health and aesthetic criteria (both of which are dependent upon the cultural context). It must also meet minimum structural standards and provide a reasonable service life. The chamber itself should be watertight and allow no accidental seepage of fluids in or out; it must be vector-proof and exclude flying insects, rats, mice, etc. It must also meet the cultural norms of hygiene and cleanliness.

Compost Toilets in the United States

Compost toilets are a relatively new form of sanitation device in North America. There are two major reasons for their introduction and recent interest in them:

1. Compost toilets use no water and therefore do not create a waste water disposal problem.
2. They offer the potential for recycling the plant nutrients (i.e. fertilizer value of the wastes by returning them to agriculturally or horticulturally useful soil.

The first reason has drawn the greatest amount of general interest. Clean potable water is becoming a scarce and most precious commodity. On the average 40% of daily domestic water consumption goes to flushing the toilet. Enormous quantities of energy are consumed both in moving water around for human use and in cleaning up the water after it is mixed with human wastes. Environmental pollution has been the result despite of the best efforts of an increasingly more complex and expensive technology.

In less densely populated areas human wastes are generally disposed of by individual household systems. The most common is the standard flush toilet (used with sewage systems) connected to a settling tank (septic tank) to collect the solids and a sub-surface soil absorption system (gravel filled trenches or leach lines) for the clarified liquid. For these systems to be designed and installed economically with a reasonable service life, the soil must be porous enough to accept the waste

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water at a nominal rate. Generally speaking, deep loamy agricultural soils are best suited for wastewater disposal. Soil Conservation Service studies indicate a large percentage of accessible land for development is unsuitable for subsoil waste water disposal. This produces a tremendous pressure to develop agricultural land and is contradictory to good land management policy. Any human waste management system that significantly reduces the total waste water discharge of a single family dwelling is looked upon with great interest by the building and development industry as well as by environmental activists.

A second major reason for the interest in compost toilets is the potential they provide for recycling plant nutrients back to the soil. This can save the dollars which might otherwise be used to purchase petrochemically-based fertilizers. Further, there is a growing group of advocates whose environmental concern extends to a desire to be more directly responsible for the reasonable management of their own waste products.

Types of Compost Toilets

There are two generic types of compost toilets: The batch collector and the flow-through design. Batch collectors provide for accumulation of wastes and compostable materials until the container is full. They are then allowed to sit and age without addition of any fresh material until the wastes are fully decomposed and ready for use as a soil amendment. A second container of series of container is used while the first is aging. The flow-through design has a sloped floor and large volume. Retention time is generally greater than two years before the end product is removed from the lower end of the compost chamber.

The basic parts of a compost toilet are:

1. The toilet structure or riser which is a seat or bench or a hole in the floor. All types of risers have a tight fitting cover to exclude flys or insects from entering and odors or exhaust gases from escaping.
2. A drop hole through which the wastes pass and which connects the seat to the compost chamber.
3. The compost chamber itself.
4. Air inlet vent which must also be constructed to exclude insects and vectors.
5. An access hatch into the chamber to remove the compost which must have a vector proof seal.
6. An exhaust vent to allow decomposition by product gases to escape.
7. Additional internal aeration or mixing devices to facilite the composting process. (See diagram #1)

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Composting for Treatment

As early as the 1930's and 1940's composting was demonstrated to be an effective means of treating large quantities of human wastes. Extensive field studies were made in China[3] and South Africa.[4]

More recent studies have been conducted in the United States. In the 1950's and 1960's Gotaas[4] and Golueke,[5] working out of the University of California at Berkeley conducted experiments with mixed municipal refuse. Their work, plus investigations in the 1970's by the United States Department of Agriculture facilities in Beltsville, Maryland[6] on sewage sludge confirmed the potential of composting for treatment. These were, however, large piles and under controlled conditions of moisture, proportioning of materials, and aeration.

Composting in History

There are not many examples of cultures that use composting toilets. In China and Japan where human waste recycling has been practiced for centuries, the wastes are collected in a regular fashion from collection or holding containers and composted or processed in large volumes at more centralized sites near the agricultural fields. The best example of successful implementation of composting toilets has been in North Vietnam where they have had a continuous program of implementation for over 15 years. They report remarkable figures of increased fertilizer production with resultant crop yield increases and recuction in parasite infestation and the spread of interic disease.[7]

A study in Tanzania subdivided the two generic types, batch and flow-through toilets, into those with floor drains in the vault to leach out excess liquid build up and those with solid bottoms (which are a necessity in areas of high rainfall and seasonally high groundwater). Their prototypes were below ground masonry vaults with covered access shafts. A five year study, from 1973-1978, indicated that batch vaults with minimal maintenance were preferable to the continuous flow type from a public health and cultural standpoint.[8]

Most of the development work surrounding compost toilets has, to date, been conducted in Scandinavia. The first patented compost toilet was the Clivus Multrum (by Rickard Lindstrum) and was an inclined mulching pit. Several commercial models have since spun off from this Clivus design, and have incorporated various innovations and changes.[9] Most sales in Scandinavia and Europe were for vacation homes with seasonable use, primarily in rocky coasts where septic systems were not possible. These compost toilets weren't actually intended for year round use and, in fact, have proven to perform more like a batch composter, with a 6-9 month rest period each year.

By 1978 the Clivus Multrum and the Toa Throne were both being manufactured in the United States and were the two leading brands on the market. Both had promising features: The Clivus has a large volume - (6-8 cubic yards) and intended use rate[10] and the Toa Throne, though

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smaller (3 cubic yards) had an aerated false bottom, or staircase, which was reported to improve decomposition rate.[11] Several smaller imports conpensated for their size with manual and electric mechanical turning devices, electric heating tapes, electric exhaust fans and aeration blowers, and electric hot plates for final sterilization and dessication of the partially decomposed end product.[9]

Owner Built Compost Toilets

National interest was arroused in composting toilets when the alternative publication media: Rodale Press, Organic Gardening and Farming Magazine; [12] Mother Earth News;[13] Compost Science; [14] etc. The imported and manufactured compost toilets continue to be very expensive. Interest in owner built alternatives was generated primarily within the back to the land movement which started in the late 60's. The state of Maine with its rocky coast line, poorly drained soils and deep frosts was the first state to allow legal experimentation with the new devices; and the first to set minimum guide lines.[15] Sim Van der Ryn drawing on Wendell Berry's experience which he had published in Organic Gardening and Farming and the Vietnam privy model,designed a number of compost privys for a Zen Buddhist monestary in Northern California. This work resulted in the publication of a technical bulletin on compost toilets by the Farallones Institute.[1] This was followed by a booklet and newsletter from investigators in Maine[16] and a more comprehensive book by Rodale Press with a variety of plans and personal experiences.[9] Used 55-gallon drums were tried as low cost batch composters by numerous rural "new arrivals" and a specific publication on drum privies was published by Peter Warshall.[17]

However, compost toilets were not generally accepted by state or local health departments or building departments. Compost toilets became a political issue in western states, notably California, as part of a general struggle over basic human rights and life style questions versus property values and bureaucratic controls. The basic concern of the Health Department was: Are compost toilets safe, sanitary, and reliable compared to the standard of the flush toilet? There was reasonable doubt to claims of compost toilet advocates that thermophilic decomposition automatically occured in a compost toilet chamber which would render human wastes stabilized and pathogen free after one year or so of composting and aging. Advocates countered with cries of dismay over the double standard applied to compost toilets operated by individuals at their own risk in rural areas versus centralized sewage systems for large urban areas that dump directly in open bodies of water during heavy rains and peak periods. There can be no quantitative scientific resolution to such discussion.

THE FARALLONES INSTITUTE AND COMPOST TOILETS

The Farallones Institute has been investigating compost toilets since 1972. Farallones President Sim Van der Ryn designed a series of compost toilets for a Zen monastery; this was followed by a publication,

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the Farallones Institute Technical Bulletin No. 1: Composting Privys in 1975.[1] In 1975 the Institute received a grant from Rodale Press to fund a field survey of existing installations to push for a more comprehensive study and analysis by local and state health officials. This study was eventually iniated by the California State Office of Appropriate Technology under the direction of the State Architect Van der Ryn in conjunction with the California State Health Department and funding from the US Environmental Protection Agency.[18] Preliminary results of that study indicated that little if any composting was going on in existing compost toilets. The material was generally undergoing low temperature moldering, often under anaerobic conditions, with a number of installations experiencing vector problems, particularly flys. There was similar experiences at the Farallones Institute's Rural Center with the concrete vault privies until an intensive management program was initiated. This program involved weekly manual turning of the compost piles with pitch forks within the vaults and the frequent addition of organic materials such as straw or grass clippings. The addition of kitchen garbage aided composting but quite often resulted in fruit fly infestation.

Management programs of the Rural Center compost toilets improved the composting action. Temperature monitoring with proble thermometers indicated thermophilic activity and temperatures above 60 degrees centigrade in the center of the piles.[19] However, laboratory analysis of six month old compost indicated viable parasite cva and larvae had survived.[20] Further, the labor requirement of the management process became too burdensome for the community.

The Rural Center as a Testing Ground

The Farallones Institute's Rural Center is a residential research community. It's growth and development has generally been experimental in nature; the residents of the community have had to live with mistakes as well as successes.

The waste systems at the Center have been dictated by the service needs of the community and the limitation of the site as well as by the philosophical, educational, and research goals of the organization. The Center is located in the Pacific coastal hills where water is in short supply and soils are tight clays with poor perculation. Standard flush toilet septic systems and their high water use were simply not an option if there was to be any water left for horticultural purposes. Furthermore, there was and is a philosophical commitment to explore alternative systems within the real life situation of the community.

Designing, constructing, and living with alternative technologies at the Rural Center also involves integrating devices into whole functioning systems. This adds a dimension of complexity to the task of evaluation and assessment but can also point out design flaws and criteria not encountered in controlled laboratory testing.

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Definition of Some Problems Encountered With Compost Toilets

Work with compost toilets over the past eight years and that of others has pointed out several problem areas:

1. Vectors: Flying insects or rodents can possibly have access to fresh feces and can act as disease vectors and contaminate water and food supplies causing reinfection or spread of interic disease or intestinal parasites.

2. Liquid can build up, especially if the toilet is overloaded, and can result in anaerobic activity. This produces odors and slows decompostion and prevents aerobic thermophilic activity. Serious overloading of a system can constitute failure and pollute the immediate environment.

3. Odor: If ventilation systems are not properly designed odors can be released into the restroom.

4. Health Issues: There is a health hazard associated with handling compost by-products or using them on vegetable crops which will be eaten raw (such as carrots or lettuce). The only insurance against this is total pathogen and parasite destruction.

Commercial manufacturers of the Clivus Multrum and the Toa Throne and several of the smaller imported units added various electrical devices in order to alleviate some of these problems. Electric fans were added to increase air flow and promote faster evaporation of liquid and increase decomposition rate by improved aeration. Electric heat tapes were also add to increase evaporation and decomposition rates. Electric pumps were installed to pump out excess liquid when it reached overflow levels. Even electric hot plates were added to some smaller units for high temperature sterilization and desication of the partially decomposed moisture laden end product. The commercial compost toilet had evolved from an energy saving idea to an energy consumptive commodity in an effort to make them more automatic and therefore more acceptable to the average user and gain acceptance from health officials.

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THE DOE STUDY

The goal of the DOE study was to utilize solar energy in lieu of electricity to help alleviate the basic problems with compost toilets. The solar devices were first used to augment existing facilities and additional systems were designed from inception with solar heating and venting systems.

Four independent studies were initiated and excuted over the two years of the grant period:

1. The design and construction of a solar pasteruization unit for treatment of 55-gallon drum waste collection units.

2. Retrofit an existing Clivus Multrum toilet, located within a greenhouse, for direct passive solar heat gain.

3. Design and construction of an owner built flow-through compost toilet with a solar hot air heating system for hillside installation. (Shop Privy)

4. Design and construction of an integrated bathroom facility (the Solar Maximus) utilizing a solar heated flow through compost toilet and solar chimney ventilation system.

Study #1 - Solar Pasteurization Unit for 55-Gallon Drum Privies

1. Statement of problem

   Drum privies are being widely usde by owner builders as an inexpensive sanitation system. The basic management procedure is to fill up a drum by daily use over a two to six month period then cap off the drum and let it sit for a year out in the weather. Drums are heated in the sun to some extent by painting them black. No thermophilic activity could take place due to the small volume and the large conductive surface area of the drum which allows heat loss at a faster rate than heat gain via composting activity.

2. Hypothesis

   A solar oven could heat the contents of a fifty-five gallon drum to pastuerization temperatures adequate to kill interic pathogenic and parasitic organisms rendering the compost safe for general horticultural use (after additional composting for complete stabilization).

3. Goal

   The thermal death point of most interic pathogenic and parasitic organisms under moist conditions is given by Gotaas as 55 degrees centigrade. A goal of raising the internal drum compost temperature to 60 degrees centigrade

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was set to provide a margin of error. A negative coliform test of the treated compost would indicate complete pathogen and parasite destruction.

3. Test Device

A solar oven large enough to accomodate a 55 gallon drum was constructed using stud frame construction with plywood walls. Studs were 2" x 6" to accomodate R-19 fiberglass insulation. Double glazing was set at a 45 degree angle for average year round performance. An insulated cover, rated at R-19 was hinged to cover the glazing at night to prevent heat loss. It had a highly reflective inner surface to act as a reflector during the day when open. (See diagram #2.)

The back door had small (⅛" diameter) ports to pass a probe thermometer. The drums were made up with ½" NPT connectors brazed into the drum wall at the quarter points. Threaded sections of ½" PVC pipe the length of a radius were capped with metal caps and threaded into the drums. The probe thermometer could measure the inside drum temperature by contacting the metal end cap at the center of the drum. The drums were positioned in the oven so that the pipe wells lined up with the corresponding parts in the door of the oven.

4. Test Procedure

Fifty-five gallon drums were used to collect human wastes from a retrofitted vault privy. The usual procedure at that time was for the privy user to add a handful of sawdust after each use. This procedure was modified to an occaisional addition of straw. It was felt that the sawdust might be too much of an insulator and impede heat flow. The thermal death point figure of 55 degrees centigrade is only accurate under moist conditions. It was assumed that damp or soggy wastes would conduct heat more rapidly.

Four drums were processed in the trials from July through September 1978. Each drum was progressively fuller and dryer as the management procedure was modified to conform closer to more prevalent habits. Solar heat gain/heat loss calculations during design indicated that the maximum heat gain by the drum would come from opening the oven only the four prime solar hours from 10 am to 2 pm (solar time). In running the trials the timing would vary from 15 to 30 minutes each day. The temperature of the drum was taken at

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the opening and closing of the shutter each day during the seven-day trail. The first drum never exceeded 54 degrees Centigrade at the 2pm closing time. During the second trial the drum temperature was checked at midnight after the fourth day and discovered to be over 60 degrees Centigrade although it had been below 55 degrees Centigrade at closing time. There was a nine to ten hour lag time between the hottest oven temperatures and the internal drum temperatures. The internal air temperatures of the oven would exceed 120 degrees Centigrade and the surface drum temperature got up to 86 degrees Centigrade. Drum #3 reached 61 degrees Centigrade during the seven-day run. A sample of supernatent was taken to a lab for coliform examination. However, due to a lab error in dilution strength for the test there were no conclusive results. When the lab error was discovered, the sample had been used up and no additional tests were possible. The fourth drum encountered early rains and cloudy weather. With never more than three straight days of sun, the drum failed to heat up adequately and the test was abandoned after a month with no further tests.

Additional Information

The drums proved to be very heavy and cumbersome to handle. Removing the contents for further processing (i.e. composting with straw and other organic wastes) was a messy and unpleasant procedure not to be recommended. Long term storage of more solid compost material (with a greater percentage of high carbon added material) and disposal by trenching after a year or so proved to be a more reasonable management procedure. Drums filled with more solid compost were lighter and easier to handle, particularly after a year of composting.

Results

The Solar Oven accomplished its goal of heating up a 55-gallon drum privy collection unit 3/4 full to a target temperature of 61 degrees Centigrade. However, due to improper lab procedures and inadequate sampling, no definitive conclusion can be drawn.

Conclusions

The rigidity of the operating schedule (i.e. opening and closing the oven at prescribed times--mid-morning and mid-afternoon for successful operation) would limit its utility to persons at home everyday. The performance of the test device during the fall indicates its usefulness is limited to full sun summer weather (at least a week of full sun at a time). However, drums could be stored for processing during the summer. The need for a relatively damp mixture to insure good thermal conductivity to reach the target pasteurization temperatures, results in a relatively anaerobic mass that must be mixed with additional organic material to be composted after heat treatment. This

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procedure proved to be very messy and unpleasant (noxious) and not to be recommended. Long term storage and final disposal of the compost in trenches around berries or in orchards appears to be a better and cheaper management procedure for drum privies.

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STUDY #2 (Clivus Retrofit)

Solar Heating of a Commercial Compost Toilet

1. Statement of the Problem

Clivus Multrum compost toilets have a generic problem of liquid build up and low rates of composting activity. Clivus distributors and the manufacturer have added electric heat tapes and electric fans to heat up the compost, improve aeration and compost activity, and evaporate the excess liquid. Electric pumps have been installed to pump out excess liquid when it reaches over flow levels.

2. Hyphothesis

Placing a Clivus in a greenhouse environment and painting the surface black will constitute passive direct solar gain and improve the performance of the compost toilet.

3.Background

Two Clivus Multrum units were donated to the Institute by the manufacturer. One was installed in the Integral Urban House in Berkeley and used by the four to six house residents according to the manufacturer's instructions. There were liquid build up problems and it had to be pumped out on several occasions. Voluntary urine seperation (use of a urinal) and installation of an electric fan helped alleviate the liquid problems.

4. Test Apparatus

The second unit was installed at the Rural Center but was overloaded by high use during a workshop season and abandoned for a year. During the DOE Study it was cleaned out and installed adjacent to a greenhouse in an insulated addition and painted black for direct solar gain. Thermocouples were installed in (1) the compost under the toilet seat (freshest material); (2) the exhaust vent near the top;(3) the upper most portion of the compost; and (4) the air inlet to the compost chamber. (See Diagram #3)

5. Test Equipment

The thermocouples were hooked up to a multichannel Data Logger Digitel Recorder that took hourly temperature readings printed out on a paper tape record.

6. Goals: (1) Maintain equilebrium between liguid loading and liquid evaporation; (2) Improve composting performance as demonstrated by elevated compost temperatures; (3) Provide a demonstration installation for public tours.

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7. Test Procedure

The Clivus was used full time by one resident of the dwelling and occasionally by guests and visitors. Biological characteristics of the compost were monitered monthly as part of the OAT Study Phase II of propriatory compost toilet installations. That data will be reported in the OAT Phase II Report.

8. Results

The clivus is on public demonstration as part of the Saturday tour program.

The Clivus compost chamber was not significantly heated by the greenhouse situation. Air temperatures inside the chamber reached a maximum of 80 degrees on the hottest summer days. This was generally within four degrees of the air inlet temperature from the greenhouse. The compost temperature stayed in the low 60's Fahrenheit and averaged 65degrees F. The maximum temperature recorded was 71 degrees F on a very hot day. After one year of use at less than half the manufacturers recommended capacity, liquid began to pond in the lower compartment. In general, a compost toilet pond at summer's end will continue to accumulate liquid during the winter months.

Although the Clivus greenhouse installation does not appear to be successful, there are several points to consider: (1)there is minimum glazing directly south of the unit (6 sq. feet). A solid glass south wall would allow more solar gain. (2) The Clivus is lower than the adjacent greenhouse and connected to it by an open doorway of 18 square feet area. There is probably minimum air circulation between the two rooms. Being lower, the Clivus is located in the coolest portion of the space (a cool sink). The insulation beside and below the Clivus is open cell polystyrene (bead board) which may lose much of its "R" value when damp (unknown at the time of installation). (3) The lower use rate may detract from the operation since there is minimal material being added to compost.

9. Recommendations

(a) Addition of more glazing for more solar gain

(b) Addition of more organic material to the compost chamber to produce a larger compost pile

(c) Higher use rate (closer to manufacturer"s recommendation of four persons/day) to increase compost feed stock.

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STUDY #3 - SHOP PRIVY

1. Statement of the Problem

Because of their space requirements large commercial compost toilets, such as the Toa Throne and Clivus Multrum are difficult to retrofit into existing dwellings. In addition, they are expensive and are prone to certain operating problems. But both Clivus and Toa Throne have design characteristics that are attractive: The size and shape of the Clivus with its internal air channels and the aerated sloped bottom of the Toa Throne.

2. Hypothesis

A large compost toilet can be owner-built of readily available materials (Hardware store, lumber yard), that combines the best features of the Toa Throne and the Clivus, as a retrofit to an existing structure, at less expense than purchasing and installing the commercial item.

Solar energy can improve the performance of the compost toilet.

3. Background

The shop privy at the rural center serves the core area around the shop including the visitors' center which is open on Saturdays. It is on a south facing slope on the east side of the shop. It gets sun until about 1 PM. The restroom facility first had a Clivus Multrum which overloaded; next it had a four-chamber vault privy which was too much work and had liquid build up problems; the third phase was a drum collection retrofit; while a fourth unit, more automatic, could be designed and built. The south slope afforded an opportunity to place a hot air flat plate below the compost chamber and would allow thermal convective heating of the compost pile. A 20' high 12"x12" vent stack was already installed which would provide adequate draw via the stack effect.

4. Goals

The general goal of the project was to provide a working sanitation system for the core area. A second was to test a new ferrocement construction technique as an easier, less expensive construction than concrete filled under block.

The specific goal of solar heating was two fold: (1) to increase the evaporation rate of liquids and thereby eliminate the need for pumping out excess liquid (with its related health risk and disposal problem) and (2) to allow autoheating of the compost to the thermophilic range for more complete treatment (i.e. pathogen and parasite destruction).

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5. Test Unit

An insulated flow through compost toilet was built under the existing rest room using ferrocement (described in the adenda under "Construction Techniques"). The air stair case concept was used from the Toa Throne. The false bottom was built of corregated cement asbestos roofing sheet scraps 24" long by 4' wide. The three sheets were mounted at a 40 degree angle from horizontal. Each sheet overlaped the one below it with a 3" overhang with a 2" gap leaving a passage air could come up through but that compost would not fall back thru. (See Diagram #4)

The access hatch on the back wall was insulated and weather striped to avoid heat loss. A plexiglass baffel inside allowed observation of the compost chamber without opening the chamber to the outside environment. A small hatch below the observation plate permitted samples of liquid and compost to be drawn.

The solar system was a simple beer can on aluminum offset plate, hot air flat plate with filon glazing approximately 18 square feet of surface area set at a 30 degree angle for summer time efficiency. The heated air entered the compost chamber below the false bottom, migrated up through the spaces between the plates and into the compost before going up and out the vent stack.

6. Test Procedure

The compost toilet was used on an open basis by the resident community and on Saturdays by visitors. A counter on the seat kept track of the use rate. It averaged 15 uses per day for the year of monitered operation. Periodic compost and flat plate temperatures were taken with probe thermometers. Data points were below the seat and a foot or so to either side, and from the access hatch through small ports in the plexiglass view port using a 36" long probe. Temperatures were taken first thing in the morning (before the sun hit the collector); around one (just before the light left the collector); and early evening. Liquid was recirculated (once or twice a week) from the lower sump and sprayed on the dryer top portions of the pile using a hand pump system (See Adenda - "Urine Recirculation").

7. Results

The ferrocement construction technique was a complete success (See Adenda - Construction Techniques - "A") It was simple and less labor intensive than the cinder block construction and it has the advantage of being insulated to reduce heat loss from the compost to a large heat robbing mass (i.e. cinderblock walls).

The toilet performed satisfactorily for its first ten months of operation. With the start of the summer workshop season and the onslaught of a ever growing number of visitors, however, the system finally overloaded and had to be pumped out several times throughout the visitor season. (See Adenda for further information about Toilet Seat and Riser Problems).

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The toilet was overloaded to about twice its design capacity (a common reality at public facilities) and the compost toilet had very little resiliance to overloading.

The solar system was inadequate to cope with the liquid problem at the overload rate. Only a long term reduction in loading rate would determine its capability as designed.

The compost temperatures were increased by the solar assist but not, however, to the desired auto pasteurization levels. Compost temperature under the seat where it was hottest often reached 120 degrees F and was generally above 100 degrees F. Temperatures at the other end were in the 60's-70's range. Air temperature inside the upper portion of the chamber fluctuated with the solar collector. The lower portion was nominally affected and stayed in the 60's-70's also.

A sample of liquid was examined to determine bacteriological and chemical quality as an indicator of decomposition. The results are not much better than raw wastes indicating minimal decomposition or stabilization. (See lab data in Adenda: Sample #1 from Brelje & Race is the solarized shop privy; #2 is a non-solar assisted Toa Throne as a control.)

Liquid recirculation appeared to improve the decomposition of the compost. Since the unit was (and continues to be) over loaded, it was cleaned out entirely which offered a chance to view the entire mass at once. Under normal operation only a portion (less than 20% of the volume) would be removed at any one time: the oldest most decomposed material. The center section below the seat and two strips on either side were well decomposed humus-like compost. These were directly below the spray of the liquid recirculation system. The outer edges were dry and only partially decomposed. The portion in the sump was soggy anaerobic foul smelling muck.

8. Conclusions

(1) Compost toilet tested was not resilient enough for a public facility with variable loading rates.

(2) The solar assisted insulated design was not adequate to facilitate thermophilic autopasteurization temperatures in the compost.

9. Recommendations

(1) Reduce loading rate to design maximum (15 uses/day or less - 4-6 persons on a regular daily basis, i.e. eliminate its use as a public facility).

(2) a. Add more holes on the liquid recirculation pipe network for more even distribution.

b. Replace the bilge pump with a sealed unit.

c. Modify operating procedure to include more pumping and recirculation.

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9. Recommendations - (Continued)

(3) Add an over flow drain to automaticly channel over load fluid to a subsurface disposal system (existing grey water line).

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STUDY #4 (SOLAR MAXIMUS)

Integration of a Solar Heated Compost Toilet Into a Complete Bathroom Design

1. Problem

The solar heated compost toilet of Study #3 was built on a hillside so that the flat plate could be below the compost chamber. On flat ground the flat plate would have to introduce hot air into the upper portions of the compost chamber. This would heat the space but warm air would not be drawn through the compost facilitating evaporation or composting.

2. Hypothesis

The static pile method of composting sewage sludge at the Beltsville, Maryland, USDA Experiment Station uses a fan to pull air out from underneath a static compost pile which draws air down through the pile and thoroughly aerates it without turning or mixing the compost. High temperatures are reached (68 -75 degrees Centigrade) which are more than adequate for pathogen and parasite destruction. A solar chimney is an alternative energy device that creates a draft which could be used to pull warm air down through the compost pile inside a privy and out to exhaust.

3. Goals

(1) Design and build an integrated solar bathroom that will meet the needs of the cabin residents and serve as a model for public viewing.
(2) Incorporate design data learned from Study #3 into the compost toilet.

(3) Promote liquid evaporation via the solar system.

(4) Generate static pile-like composting conditions via the solar system,(i.e., generate auto pasteurization thermophilic temperatures in the compost).

4. Test Unit

The Solar Maximus was conceived as a further estension of our tests of the use of solar energy with compost toilets. Further, it was designed as a model of energy efficiency for a particular end use: The Bathroom. (See Diagram #5)

The bathroom incorporates several components including:
- A breadbox solar water heater with wood fired backup system
- A drum wall space heater for the shower
- A greywater filter system for recycling the shower and lavatory water for landscape irrigation

The structure is free standing but could also be built into a south

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facing portion of a house or other structure. The bathroom demonstrates to the public a new concept in looking at alternative energy sources in terms of their end uses. The bath room was designed as a prototype for a system to serve an average family of 4 to 6 persons. Water conservation is a key feature of the bath room with flow restrictors on the sink faucets and a low water shower head. An on-off valve on the shower head permits stopping the shower flow while lathering without losing the mix setting of the controls. The drum-wall space heater keeps the shower at a comfortable temperature so the user is not dependent on a flow of water for warmth. In the summer, all the waste water can be filtered and reused for landscape irrigation.

The compost toilet was built with a ferrocement stucco technique described in another section. An "air stair case" bottom similar in design to the Toa Throne was constructed from 3/4" ferrocement slabs overlapping 3" with a 2" air space between and cast into 2" x 3' concrete beans set at a 30 degree angle. The six cubic yard internal volume is the same as a commercial Clivus Multrum. The solar bath room is on flat ground. Heated air enters the composting chambers by way of a collector which was placed at a 45 degree angle off the south side of the building. A solar chimney 20 feet high draws air out from under the sloping bottom which draws the heated air in the vault down through the compost and up and out the stack. At night and on cloudy days, a green house venting mechanism closes the solar chimney and opens a 4" auxillary vent located at the highest point in the compost chamber (next to the seat). The solar chimney opens on a sunny morning when it heats up enough to actuate the heat piston mechanism and at the same time the auxillary vent closes (butterfly valve).

5. Results

The solar bath room has been operating for approximately one year. Adequate (130 degree F) hot water is produced by the bread box for about four showers/day during the summer (April-September); the wood backup must be used during the rest of the year. The drum wall space heater fluctuates between 50 degrees F and 70 degrees F and is generally around 65 degrees F at late afternoon, early evening when most showers are taken.

The compost toilet was overloaded its third and fourth month of operation by 25 Peace Corps trainees who used it as a urinal. The liquid level reached its maximum capacity at the end of the two-month training program and the loading rate returned to design normal. The level remained constant for two months, then slowly dropped as days lengthened and there were fewer periods of cloudy, rainy weather. By the end of May, the excess liquid was all evaporated. The solar system proved able to evaporate excess liquid.

The compost temperature reached a maximum of 93 degrees F but averaged approximately 85 degrees F with a 3-5 degree F daily fluctuation in temperature. Thermophilic auto-pasteurization temperatures were not reached.

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Compost chamber air temperatures varied radically (40-50 degrees F) each day in correspondence with flat plate temperatures. There was one or two hours lag time between air temperatures and flat plate maximums and minimums.

The solar system did not function to increase ventilation as expected. Temperature data indicated that the top of the chimney was cooler than the bottom which was in reverse of the stack effect. Instead of working to draw air out of the compost chamber, the chimney proved to be the bottle neck of the system. The solar flat plate forced super heated air (130 degrees F plus) into the compost chamber faster than the chimney could exhaust it. This positive pressure in the compost chamber forced exhaust gases up through the seat into the rest room causing terrible odor problems. When doors and windows were opened to vent the odors, the situation was actually worsened by creating cross ventilation that drew more exhaust gas out (a sealed rest room would offer less avenue for release of the positive pressure within the compost vault).

Design of the chimney and flat plates were partly to blame. The chimney had an insulated back wall but the sides were uninsulated (i.e. 2x6 board with siding overlay). The heat loss through 20 square feet of chimney side, for the 20 linear feet of travel must have been significant to its operation. The size and capacity of the chimney and flat plate were not properly matched.

Although the throat (115.5 sq. in.) and surface area (38 sq. ft.) of the chimney were greater than the corresponding values (86 sq. in., 20 sq. ft.) for the flat plate, their angles (90 degrees vs. 45 degrees) and mode of operation is significantly different.

The chimney had 1.34 times the throat area as the flat plate. In comparison the shop privy (Study #3), which has a flat plate inlet throat of 62 square inches with 15 square feet of flat plate surface area vs. a 168 sq. in. vent stack throat with no solar assist or a ratio of 2.71 chimney to flat plate, performed with much less odor. In lieu of this experience, the down draft concept used in the Maximus should be seriously questioned. Regardless of the performance of the venting system, there will always be some positive pressure under the seat with the vent lower and this pressure will be released when the seat is raised for privy use and odors will be forced out.

The odor problem in the Maximus was greatly reduced by shuting off the air inlet to the flat plate. Flat plate temperatures increased but compost chamber temperatures declined and chimney temperatures indicated normal performance via the stack effect (i.e. higher temperature at the top than at the bottom). Some odor problems, however, have persisted.

To briefly summarize these results:

(1) The solar heating process did not facilitate autopasteurization compost temperatures by thermophilic aerobic decomposition.

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(2) The solar system was able to evaporate the excess liquid, but this drying process had an adverse effect on the composting of the upper portions of the pile which were desicated and did not decompose.

(3) The solar chimney and flat plate were not evenly matched for flow rates. The flat plate forced more hot air into the compost chamber than the chimney could exhaust, generating a positive pressure under the toilet seat that led to extremely bad odors in the rest room.

6. Conclusions

The residual odor problems that persisted even after the solar system on the Maximus was altered brings up two basic questions.

Does the evaporation of such a large volume of urine from a compost toilet cause more problems (i.e. odor generation) than it solves (i.e. reduction of liquid build up)? From the stand point of nutrient conservation, in light of the fact that half the human bodies excreted nitrogen is in the form of liquid urine, does it make sense to try and evaporate this liquid off (thus volitizing the nitrogen as ammonia and losing it)? Or should the nutrient rich liquid be drained off and used for soil fertility enhancement. Utilization of liquid drainage poses health risks unless the liquid is totally contained by a subsurface system (or somehow sterilized before use). Capturing urine before it enters the compost system would have less associated health risk but poses other hygenic, aesthetic and technical problems. (See Adenda on urine separation). These questions require value judgments in setting goals for successful and desirable compost toilet operation as well as further study.

7. Recommendations

(1) The Maximus should be altered to allow the compost chamber to exhaust at its highest point into the solar chimney instead of attempting a down draft to pull air through the compost.

(2) The flat plate should have restricted air flow to match the exhaust capacity of the chimney.

(3) The auxiliary vent should remain open at all times.

(4) The baffel on the chimney should be moved to the top to avoid holding a 20' column of cold air at start up in the morning. This should accelerate start up of the chimney.

(5) Loading rates should be more strictly regulated through controlled access to the facility.

(6) If desication and uneven composting still occur after the

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first five recommendations are met, the flat plate structure should be converted to a greenhouse like structure by removing the metal sheets, insulation and backing and adding some storage mass like water bottles or rocks. (See diagram #6)

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GENERAL RESULTS AND CONCLUSIONS OF THE STUDY

1. The use of high temperature physical solar heating devices to alleviate generalized problems and improve the composting activity of compost toilets was not successful. Composting is a biological process not a mechanical one. The solar devices used in the study generated temperature and moisture extremes which were not conducive to bacterial decomposition. Since the basic intent of the study was to improve the composting process within the toilet chamber, selection of a solar device atuned to biological processes (i.e. a greenhouse) should prove more advantageous. It would moderate the temperature and moisture extremes while giving the compost an overall higher temperature environment.

2. Compost toilets are not a clean machine equivalent to the porcelain bowl. There are odor problems from time to time. Flys can have access to fresh feces via the toilet seat and serve as vectors. Rats and mice have a propensity to gain access to the compost chamber since it is an ideal nesting environment with an ample supply of food. The compost pile is subject to overloads and requires some basic understanding and management on the part of the owner user. Solar energy alone cannot make compost toilets automatic and trouble free (and thereby useable by the average flush toilet trained American).

3. Ferrocement stucco over insulated stud construction promises to be an easy and inexpensive construction technique for owner built compost toilets. More extensive use over time will be needed to test its durability.

4. Hard filled surfaces that are easy to clean and maintain (or their equivalent such as formica) are essential for owner built compost toilet benches and drop holes.

5. Liquid recirculation promises to alleviate to some extent the problem of differential moisture content (and consequently differential decomposition throughout the pile.

GENERAL RECOMMENDATIONS

The two owner built compost toilets show promise of nominally serving the sanitation needs for a single family dwelling on a seasonal basis (second home, vacation cabin, etc.). Further monitoring and study of the existing units with the recommended modifications at controlled loading rates (below design maximums) will be necessary to verify their potential.

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ADDENDA

Financial Statement

Construction Techniques

- . Ferrocement
- . Drophole Structure

Urine Separation and Recirculation

Venting

- . Wind Turbine Cap
- . Solar Cell Fan
- . Solar Chimney

Laboratory Data

Diagrams

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FINANCIAL STATEMENT

Expenditures under the grant are listed according to the Farallones Instutute Functional Accounting System. Salaries, subsistence allowance, payroll taxes, and services benefits cover the principal investigator and an assistant for the duration of the study. Materials, permit fees, consultants and services (other) are direct costs expended by the study. Other costs represent overhead to the Center.

The total material cost was $3,500. An approximate breakdown of costs would be: Solar bath room $2,500; shop privy $600; Clivus installation $400. The solar oven which was built before receipt of funding cost was approximately $250.

These costs represent actual purchased materials and do not reflect labor or materials out of stock(which was considerable in some cases). The solar bath room contains closer to $3,500 in materials.

A similar retrofit project to the shop privy (without solar assist) was constructed at UC Santa Cruz in 1978 for approximately $750 in materials (no labor charged).

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GRANT EXPENDITURES

EM-78-G-03-1978

Salaries	$ 1,748
Subsistence Allowance	2,677
Payroll Taxes	280
Insurance and Benefits	161
Overhead	1,899
Total Administration	6,765
Building materials and supplies	3,553
Permits, fees, inspections	133
Shop expenses and maintenance	80
Total Construction	3,765
TOTAL	$10,530

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CONSTRUCTION TECHNIQUES

A. Ferrocement

The development of a ferrocement construction technique in compost toilets was made possible as part of the DOE Study. Ferrocement proved to be a very suitable material: low cost, faily easy to use, and the expection is that it will be long lived.

The original compost toilet at the Rural Center was built of mortar filled cement blocks on a concrete slab. This type of toilet is easy to construct, water tight, impermeable, durable, and can be made vermin and vector proof. However, the dense materials rob heat from the compost pile. A construction material was needed that had minimum mass yet retained the other qualities of the concrete block. Commercial toilets are made from various types of molded or spun plastics, and fiberglass reinforced resins. Plastics require special equipment. Fiberglass can be used by the owner-builder but it is expensive and the resins are toxic and can adversely effect the health of the user without proper safety equipment.

Conventional stud frame construction was desirable since it is the most common and widely known construction technique and the glass wool insulation designed for use in stud walls is the least expensive type of insulation. But plywood or hardboard sheathing is inappropriate due to the difficulty of sealing the surface and joints to be impermeable against urine. Ferrocement was the material we finally decided upon for several reasons: Cost; availability of materials; ease of construction with simple tools; strength; durability; and water tightness.

Ferrocement is basically a dense rich cement stucco plastered through layers of wire mesh or netting. The technique that was employed used galvanized expanded metal lath tacked to the studs over a layer of heavy tar paper using firing nails that held the mesh ¼" out from the tar paper. A relatively dry (damp but not wet) cement stucco mix of one part plastic cement to 2½ parts sand was forced through the mesh to the tar paper completely filling the ¼" space and covering the mesh ¼" plus in thickness. The completed shell was approximately 3/4" thick. When all the mortar had been applied, it was troweled and worked to a hard smooth surface to insure a dense water tight seal. As an added safeguard the floor and the first 12" of wall were coated with Thoroseal (a silica based concrete sealer). The upper walls were coated with fibrated asphalt emulsion making the chamber dark and non-reflective. The ceiling of the chamber was ½" exterior plywood (CDX) covered with 6-mil vinyl film attached with linoleum cement, then coated with two coats of fibrated asphalt emulsion. Butyl caulk was used to seal the seam between the walls and the ceiling. The expanded metal lath comes in 24" widths so wherever possible the studs were placed on 24" centers. When a seam in the lath did not fall on a stud and additional block was added; all seams were nailed approximately every 3". Right angle corners were rounded to a 1½" radius for wall to wall and 3" radius from walls to floor to avoid cracking. A wooden strip was nailed into the corners to form the radius and provide a nailing surface for the mesh. To finish the top edge of the ferrocement shell so that itmet flush with the ceiling, a scrap plywood

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strip was nailed to the top plate protruding out 3/4" (the thickness of the shell). The wall was then plastered up to the plywood and struck off leaving a straight smooth edge.

B. Drophole Structures

The draw hole structure and toilet riser is a particular problem with owner built compost toilets. Commercial toilets come with either fiberglass or plastic cylinders which have a smooth washable surface. The simplest material for the owner builder to use is a large plastic bucket or small plastic trash can made of a dark color. The bottom of the bucket or trashcan is cut out leaving a 1" lip around the edge. This lip is attached to the underside of the seat platform with butyl caulk and screws with washers. Ferrocement was found to be an unsuitable material because of its rough texture. Urine and feces adhere to it and lodge in surface irregularities making it difficult to clean and eventually causing odor and insect problems. Wood or hardboard are also difficult to seal adequately. Epoxy paint does not seem to be moisture proof under the warm moist conditions at the top of the privy vault. Varethane or fiberglass resins based on polyurathane are unsuitable because they are dissolved by urine which contains uric acid (a solvent of urethane). Wooden tops for privy seat platforms have also proved very problematic. Although rustic looking and aesthetically pleasing to the eye, they are difficult to seal and keep clean. They eventually become urine soaked which causes odors and attracts insects and arachnids (particularly small spiders and tiny mites). Hand tiled surfaces have proved to be the easiest to maintain and keep clean. Tile shops sell complete kits for home installation and offer a variety of colors and styles. The privy bench and drop structure for the solar bathroom were made as one continuous tiled surface over a ferrocement base using 1" square white tile.

The drop hole structure for the Clivus was a hard glazed ceramic collar made at the Center's ceramic studio.

Toilet Seats

Commercial compost toilets have special toilet seats and covers that make a positive seal when closed. However, for owner built models regular flush toilet seats are not easy to seal. Neoprene foam weather stripping absorbs urine and compresses flat after about six months of use. An alternative to sealing the toilet seat and lid is to hinge the toilet seat out of the way when not in use and use a seperate tight fitting plug for the drop hole.

The shape of a standard toilet seat is designed to support the user primarily from the thighs. However, a standard toilet is 16" high. The natural evacuation position for humans is a squatting position that raises the knees up against the chest causing pressure on the abdomen and opening the buttocks for easier discharge. High toilet seats do not facilitate evacuation of the bowels and some authorities attribute the high incidence of constipation and hemorrhoid problems in western man, in part, to the 16" high toilet throne. For the DOE studies, we decided upon 10" high benchs that are broad enough to afford a comfortable

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perch for squatters and also forces sitters into a semi-squat position by its geometry. This lower bench required a redesigned toilet seat to support the user evenly by the buttocks. The final shape was similar to an old fashioned tractor seat with a hole in the bottom and in front for access.

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URINE SEPARATION AND RECIRCULATION

During the grant period we experimented with solutions to the problem of liquid buildup and odors. The average adult excretes a quart of urine daily. If even half of this amount is deposited in a compost toilet, then a toilet designed for 4 or 5 people can collect liquid at the rate of 1/2 gallon per day. During extended periods of high humidity when evaporation is reduced this liquid accumulates to excess levels. For example, if only half the liquid is able to evaporate, 30 gallons can accumulate in a four-month period. If contained, this liquid would cause anaerobic conditions in the lower portions of the compost chamber which causes odors and stops the rapid biological stabilization necessary to produce usable end product compost. Usually, however, such an excess of liquid overflows out the access hatch; this would constitute a failure of the system.

Liquid can be evaporated by induced means. This was a major reason for utilizing solar heating and drafting. Another approach would be to collect urine and feces separately for different modes of treatment and utilization. There are several advantages to this approach. Urine can be used more directly because it requires little or no treatment; urine is essentially sterile because of its high salt content and the liberation of ammonia by the breakdown of uric acid; and it does not contain the intestinal pathogens or parasites that can be found in feces. Because urine contains on half of the body's daily excreted nitrogen, separate collection and prompt re-use would be advisable from the standpoint of conservation of nutrients. Much of the ammonia in urine is volatized and lost if it must be evaporated from the compost chamber.

There are two basic modes of urine collection. One is a separate urinal or urine toilet. The second is a urine collector built into the drop structure of the compost toilet. Both have their advantages and related problems.

Ceramic wall mounted urinals are available commercially for male users but they are not appropriate for female physiology. We installed five-gallon plastic buckets with removable lids and a toilet seat that would set on the bucket with the lid removed. After 24 hours, urine starts breaking down and odors are formed; the process is rapid in warmer weather with noticeable odor the second day. In winter months, a bucket could go three or four days but regular maintenance was a necessity. In an attempt to avoid odors yet permit longer maintenance intervals, various materials were added to the buckets as absorbents: dry earth, sawdust, (particularly redwood), straw, and various combinations. They did not significantly prolong storage length without odors, but they did adversely increase the weight of a bucket to be managed (carried to a compost site).

A permanent installation with a pipe to carry the urine elsewhere offered some advantages, particularly for odor control. The first such installation was a funnel attached to the front of a squat plate drop hole. The privy had a plywood floor with a 2x4 framed drop pole painted with several coats of exterior deck paint. The funnel was screwed to

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the front 2x4 with silicon seal around each screw. The bottom of the funnel was cut off to an inch in length and was forcibly screwed into a 3/4" RVC threaded elbow adapter using a gob of silicon seal for thread seal. The 3/4" PVC pipe went around the drop hole and back out the privy vault wall to a five-gallon plastic container (recycled cooking oil container with a handle and valved 2" cap) set under the steps bu accessible. It was easy to see the liquid level through the translucent walls of the plastic container. The 3/4" PVC pipe became clogged with straw and was replaced with 1½ ABS drainpipe with threaded cleancuts in T installed at locations for elbows so the whole line could be cleaned out if clogged. The plastic containers were easy to carry and the valved spout facilitated application of the liquid to compost piles or into mulch around fruit trees.

Permanent urine collectors installed in toilet drop structures or risers have been more difficult to perfect and work is continuing.

There is some precedent for successful urine separation at the toilet. One of the fore-runners of the indoor privy before widespread introduction of the flush toilet was the earth closet. It had a catcher in front that channeled the urine into a pail filled with sawdust. Feces fell straight into a wash tub and was covered with a "dry flush" of powdered earth. Only the concept has been mentioned in the literature, however, and detailed plans or diagrams of the device have been difficult to obtain.

Development of the urine separation concept is still evolving at the Rural Center. One proposed but untried method would use grey water from the handwashing sink to flush out the line of the urine collector to avoid the odor problems. The seat would need to be placed lower, thus raising the users closer to a squat and projecting the urine stream slightly forward to facilitate collection. Further work in this field is required.

Urine Recirculation

Another concept more loosely connected to composting is urine recirculation. Compost toilet piles tend to be soggy on the bottom where the liquid accumulates and dry on the top from evaporation. This drying effect is further magnified by solar heating. However, the liquid did not seem to wick up through the compost very rapidly so the end result was an anaerobic zone on the bottom of the pile, a moist composting zone in the middle, and a dry and therefore biologically inactive layer on top. It was hypothesized that drawing off the liquid from the bottom and spraying it over the top of the pile would increase evaporation of the liquid, dry out the lower layers, and moisten the upper layers thus facilitating more rapid decomposition.

Two different systems were tried, one in each of the solarized owner built toilets. The first system used a piston type plastic bilge pump from a marine supply store and a pipe network of ½" diameter PVC pipe with 1/16" holes spaced about 12" apart that was hung from the vault ceiling with holes pointed down. Each stroke on the pump would move

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approximately one pint of liquid. Spray was not very even and tended to be tight streams that saturated a small portion of the pile. Smaller holes drilled at different directions would probably remedy this problem. Mist irrigation emitters for greenhouses were avoided because of anticipated clogging problems from suspended solids or salt crystal accumulation from evaporation. The bilge pump had no effective scavenger gasket or packing around the plunger rod. The liquid leaked around the plunger with each stroke and ran back into the sump through fly screening. Though adequate for experimental purposes, it would not be feasible for normal operation. Other more expensive brands of marine piston type bilge pumps might prove more satisfactory but these were not investigated.

A second system used an all plastic enclosed diaphram pump also designed for marine bilge use. Its ends were made for poly tubing so it was chosen for the distribution network. The brand new pump was difficult to prime and the one-way valves clogged easily with particles, greatly reducing its efficiency during break-in testing. The barb-ended connection for the poly tubing which screwed on over the one-way flapper valve broke off during final installation and was not replaceable. The system intended for the privy portion of the solar bathroom is still under development.

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VENTING

Decomposition of organic matter by bacterial activity produces gaseous by-products, primarily carbon dioxide and water vapor. In a compost toilet, ammonia is generally liberated from the breakdown of urine and there can be mercaptons (sulfur containing organic gases that have strong odors) released from anaerobic fermentation. These gases must be vented from the compost vault to prevent odors in the restroom and to allow the compost pile to breathe and draw in fresh air for further bacterial activity. In general, a straight high vent stack will facilitate evacuation of the warm gases which will rise up and out. It was hypothesized that exhausting the gases at a higher rate that offered by the stack effect would further reduce the chance of odor in the restroom and increase aerobic decomposition since oxygen is often a limiting factor to rapid composting. Commercial manufacturers have installed electric fans to increase ventilation. Three solar devices were investigated to improve ventilation: (a) a wind turbine vent cap; (b) a solar cell powered fan; and (c) a solar chimney.

A. Wind Turbine Vent Cap

Wind turbines are widely used for venting attics and commercial buildings. It was felt they might improve the draft from a privy. A 10" diameter cap was installed on the Clivus Multrum. The regular 6" diameter vent pipe was placed inside a 10" stove pipe with glass wool insulation packed around it to avoid a "cold stack". After installation of the vent cap it was discovered that the US Forest Service Equipment Development Laboratory in San Dimas, California had run wind tunnel tests on turbine vent caps simultaneously with straight open pipes and found that vent caps actually impeded air flows until wind speeds reached approximately five MPH. However, straight stacks are not practical because they let the rain in and all caps impede exhaust to some extent. The study failed to compare a standard vent with a turbine vent cap. Turbine vent caps are approximately three times as expensive as a standard. No conclusions can be drawn.

B. Solar Cell Fan

A solar cell array with a 6 volt 1.5 amp output (full sun light) that powered a small DC motor (approximately 1/16 HP) fan was loaned to the Center by the US Forest Service Equipment Development Lab. It was installed in the first solar heated owner built compost toilet prototype. The array was mounted on a movable stand that was repositioned each month to be perpendicular to the noon sun. There was a noticeable decrease in odor when the fan was in operation, but this could not be qualified. The cost of the unit (approximately $350.00) would make it too expensive for compost toilet applications. However, its pattern of operation coincides exactly with the operation of the flat plate collector heating the compost vault. When the sun is out a large volume of olar heated air rises up and into the compost vault causing a positive pressure. The pressure is released up the vent stack but air comes in faster than it can rise by the stack effect. The fan which operates at the same time as the collector helps draw out the heated exhaust gases and reduces the vault pressure. Without the fan the

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gases escape into the restroom whenever the seat is raised for toilet use--an odorous surprise. If the stack is made large enough to exhaust at the same rate as the flat plate input, then it is too large of a heat loss during the night and cloudy days. Cold air drops down the stack and forces odors out the seat and into the rest room.

C. Solar Chimney

The solar chimney vent system was an attempt to remedy these situations. The chimney is a verticle flat plate 20' high, 2' wide, and 5½" deep. A 4" auxillary vent is enclosed within the insulated north wall of the chimney. A greenhouse venting mechanism controls the venting. On sunny days the air warms in the chimney and the venting mechanism opens a trap door at the base of the chimney and at the same time closes a butterfly valve in the auxillary vent. The solar heated air rises up the chimney and creates a draft which pulls exhaust gases out of the compost vault. After the sun leaves the chimney surface, the process repeats itself. The acutating mechanism closes the trap door and opens the auxillary vent next to the toilet seat.

The operation of the chimney has been problematic at times. A large opening at the top is necessary to avoid stagnation of the air flow out at a restriction. The top must be protected from rain water and the prevailing wind. A north facing scope was decided upon for simplicity. Storm winds are out of the south and sea breezes come out of the west for the Occidental site. Since the outlet was screened to prevent entry of flies, the outlet area was enlarged to four times the throat area of the chimney to avoid restriction of the air flow. (See diagram for shape of the chimney and top exhaust.)

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[redacted]

LABORATORIES 425 SOUTH E STREET P. O. BOX 1895 SANTA ROSA, CALIFORNIA 95403 TELEPHONE (707) 544-9807

BACTERIOLOGICAL EXAMINATION OF WATER

For Farallones Institute
15290 Coleman Valley Rd.
Occidental, CA 95465

Date Reported March 27, 1979

Collected by

Analysis Number	Date Collected	Date Completed	Sample Source		Coliform MPN/100 ml	Safe	Unsafe
379-2839	3-23-79	3-26-79	Sample #1	FECAL:	390,000.		
				TOTAL:	390,000.		
				FECAL STREP:	≥2,400,000.		
379-2840	3-23-79	3-25-79	Sample #2	FECAL:	≥24,000,000.		
				TOTAL:	≥24,000,000.		
				FECAL STREP:	≥2,400,000.		

BACTERIOLOGICAL SUMMARY

Scheduled System Samples, this report:
No. samples_____
No. samples with 3 or more + tubes_____
No. 10 ml. tubes_____ No. + 10 ml tubes_____

Analyst [signature]

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BRELJE AND RACE

[redacted]

LABORATORIES 425 SOUTH E STREET P. O. BOX 1895 SANTA ROSA, CALIFORNIA 95403 TELEPHONE (707) 544-8

April 3, 1979

Farallones Institute
15290 Coleman Valley Rd.
Occidental, CA 95465

Gentlemen:

The results of analyses performed on samples collected and submitted on March 23, 1979, are complete and tabulated below:

Analyses Number	Sample Description	BOD 5 day @ 20°C mg/l	Total Organic N mg/l	Total Solids mg/l
379-2841	Sample #1	900.	780.	35,000.
379-2842	Sample #2	1100.	780.	16,000.

Very truly yours,

BRELJE AND RACE LABORATORIES

J. AMUNDSEN, Director

JA:ym

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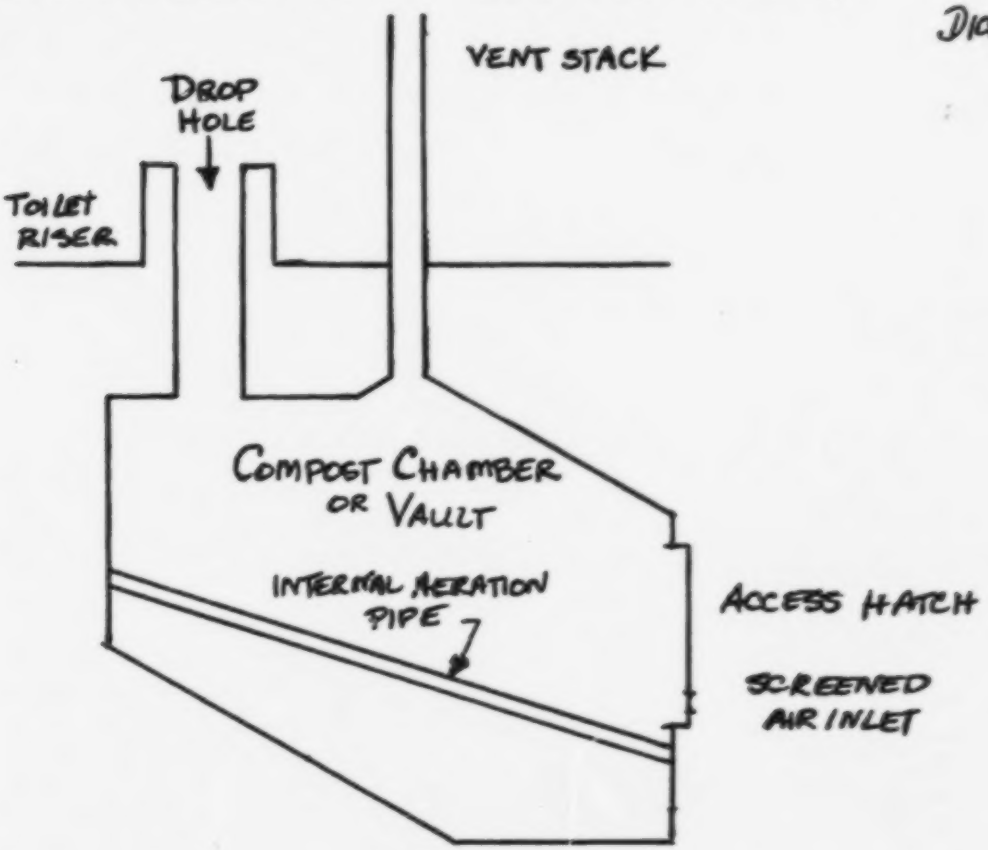
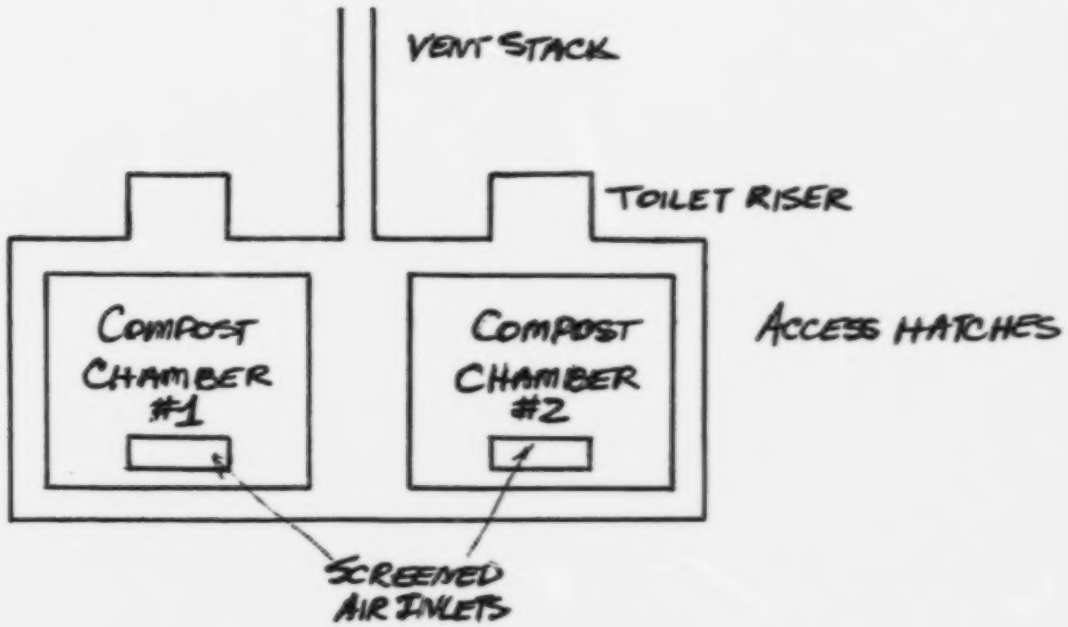
General Parts of A Compost Toilet

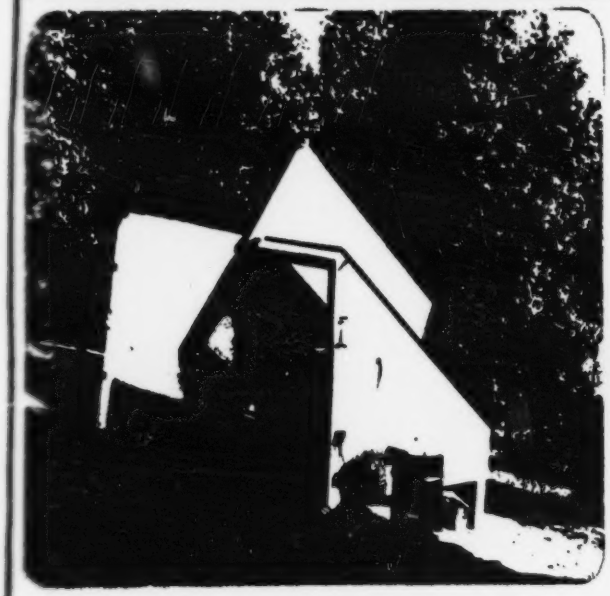
Diagram #1

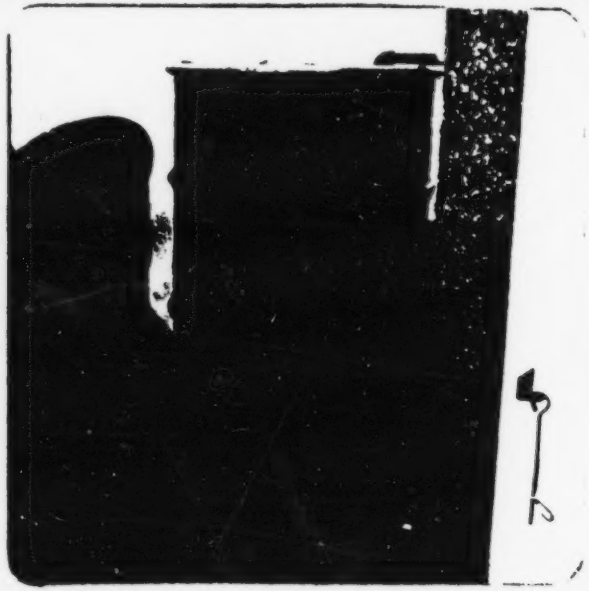


A. Flow-thru Design



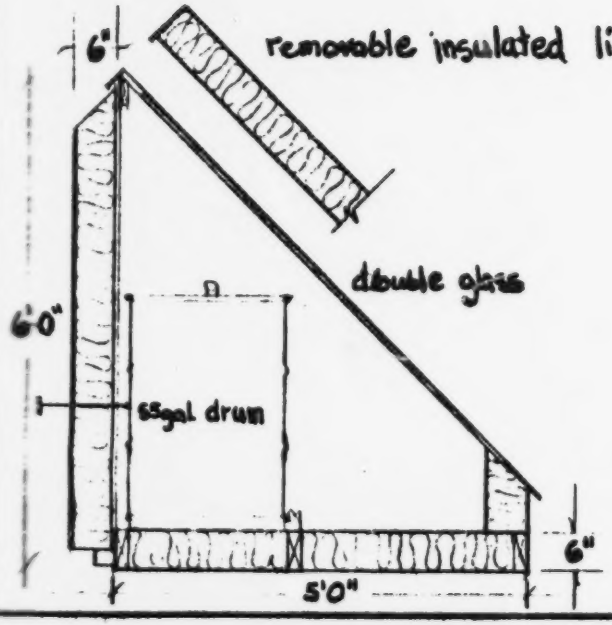
B. Batch Composter

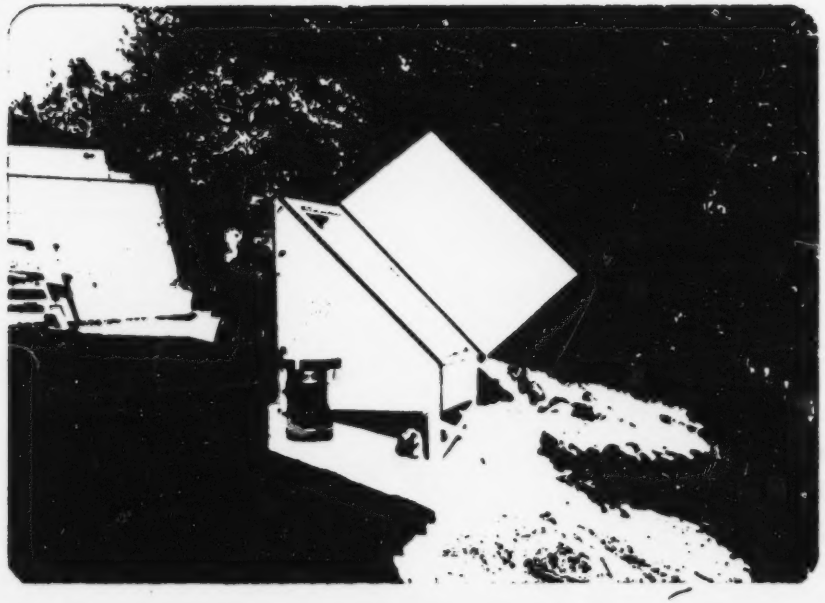




Solar Pasteurizer
for
55 gal. drum
Collection Units

Diagram #2





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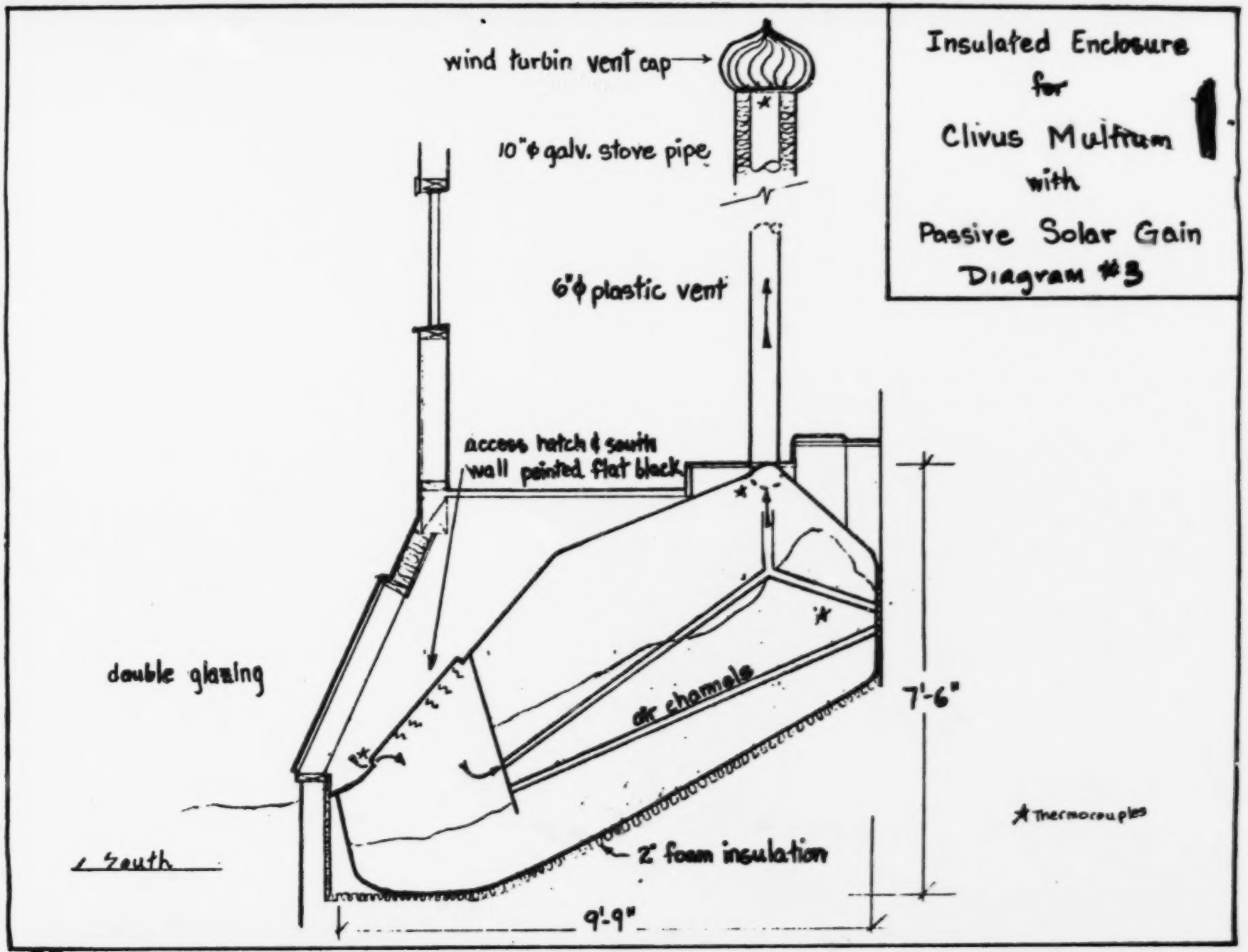

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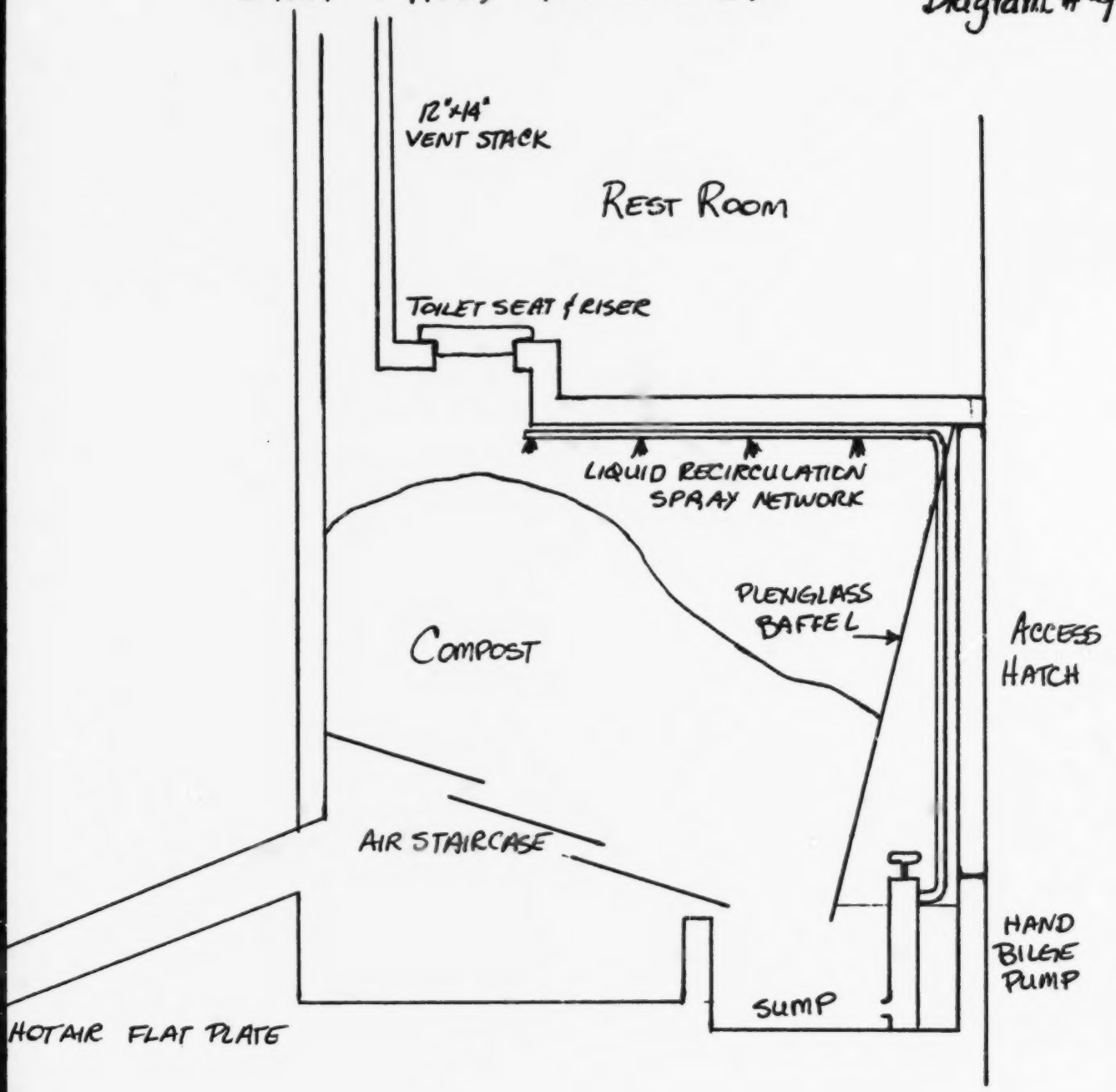
SHOP PRIVY (STUDY #3)

Diagram #4



WER BUILT SOLAR HEATED FLOW-THRU COMPOST TOILET

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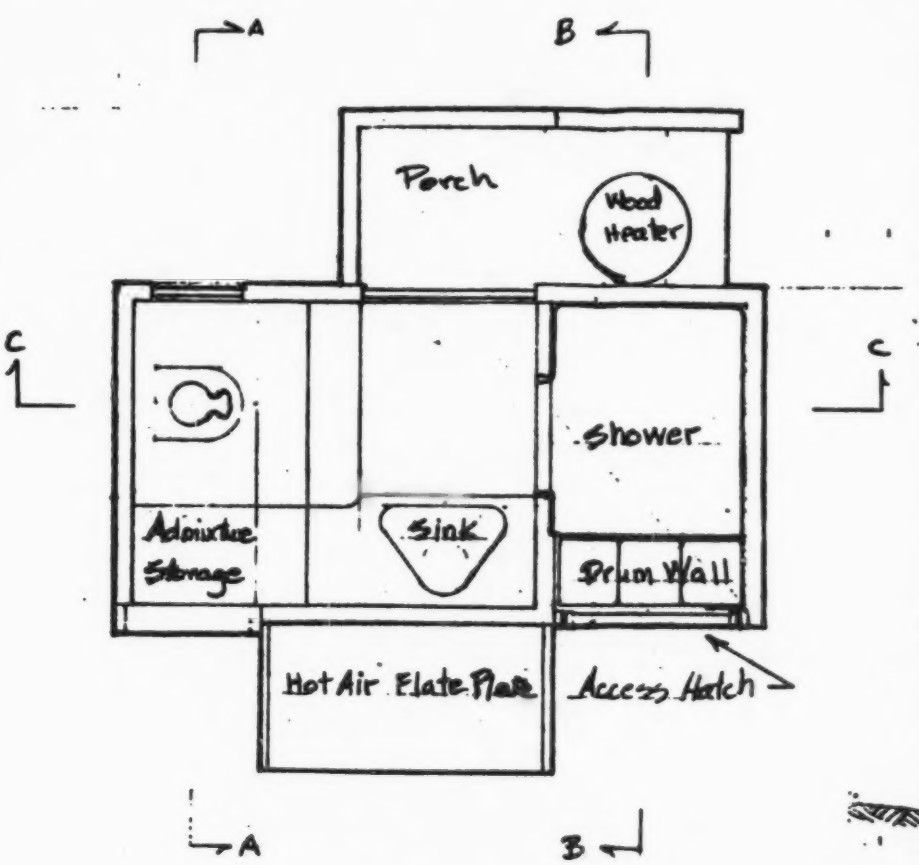
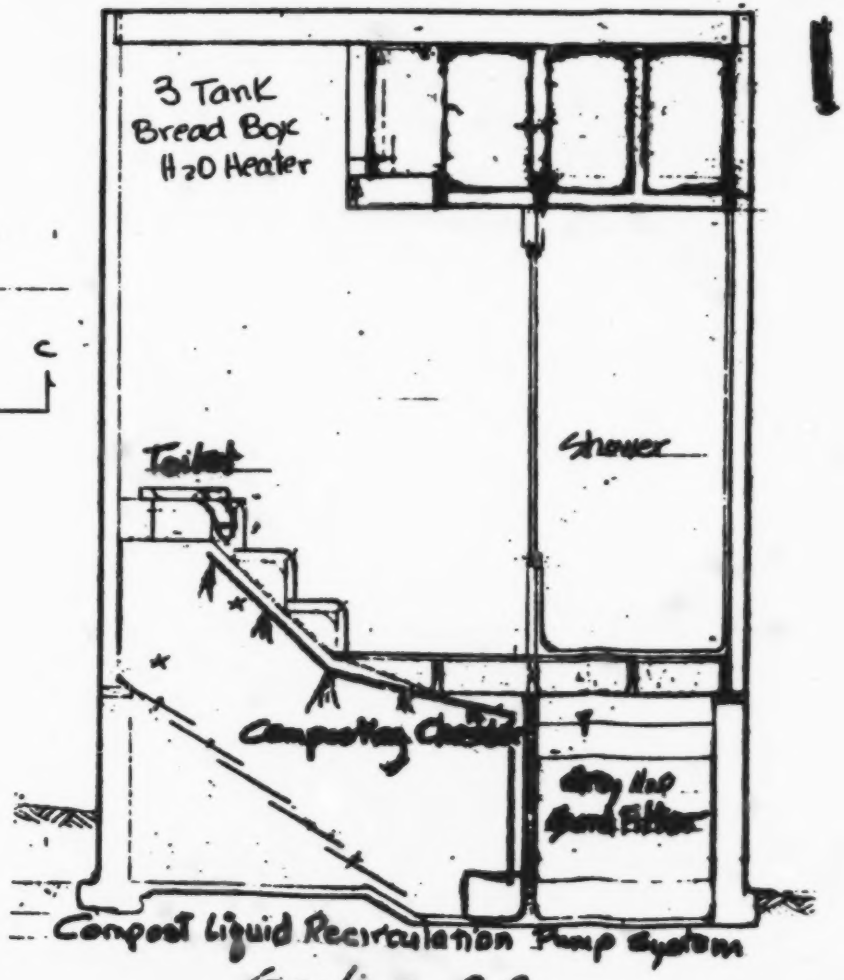


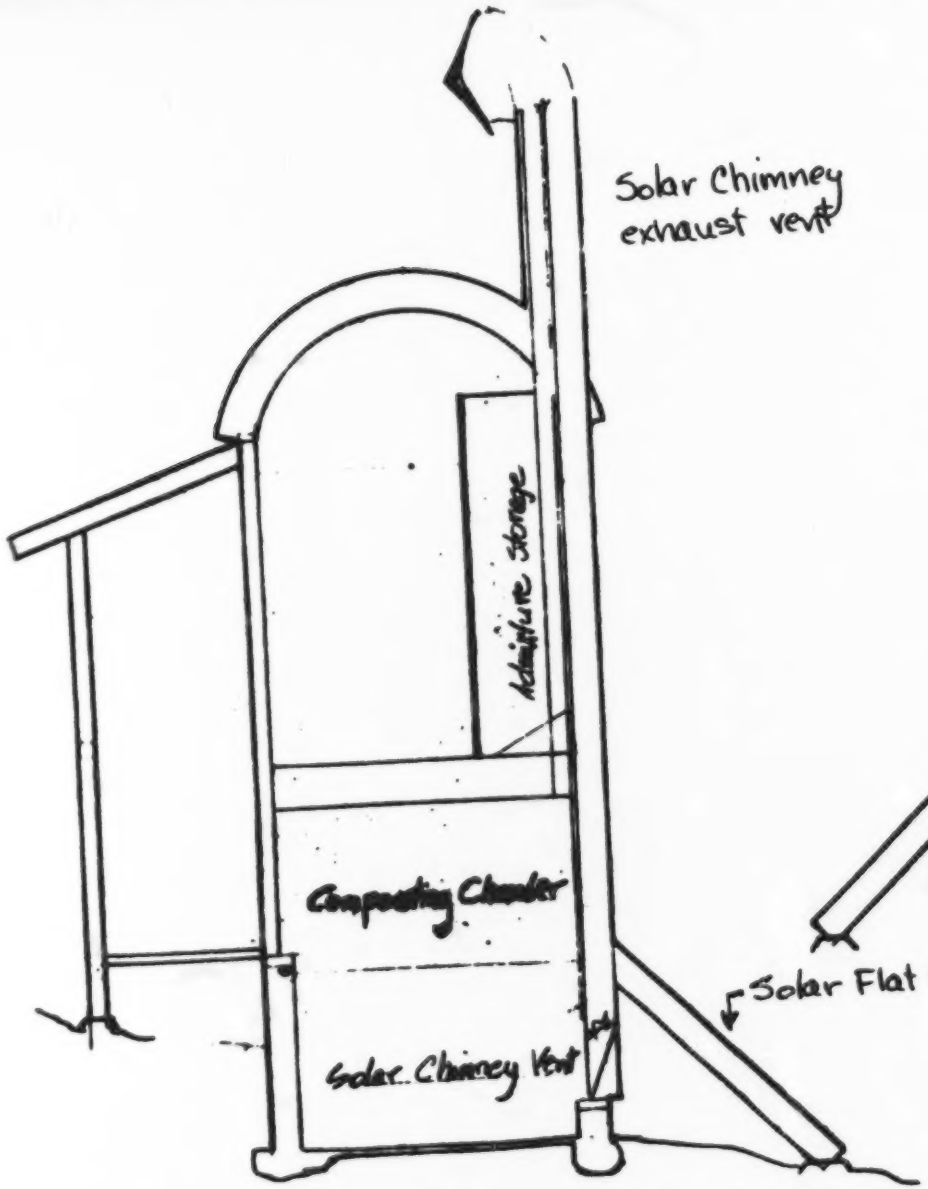
Floor Plan



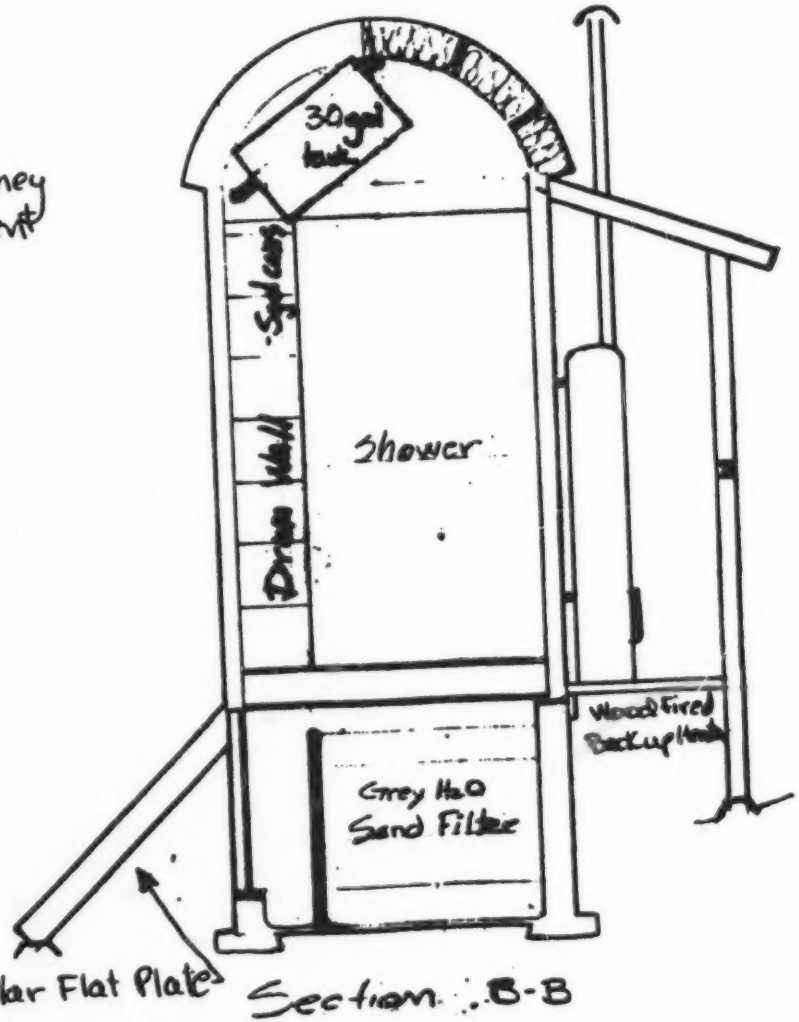
Section C-C

SOLAR BATH ROOM

Diagram 5a.



Section A-A



Section B-B

SOLAR BATHROOM

Diagra 56.

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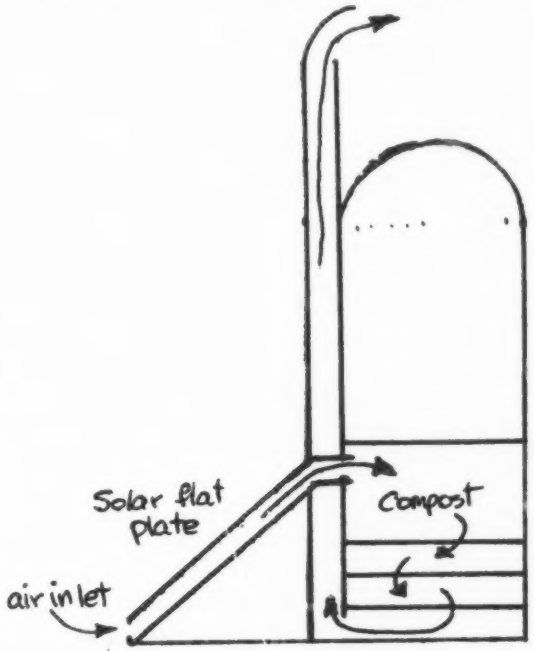
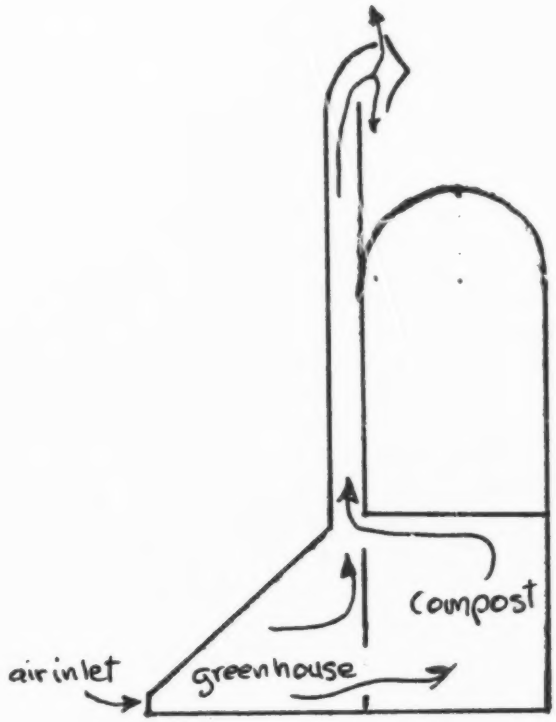
SOLAR MAXIMUS & PROPOSED RETROFIT Diagram #6

[redacted]



Present mode of operation

High temperature Flat Plate Heating



Proposed retrofit

Lower Temperature Greenhouse Environment

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